

Flavor SU(3) analysis of charmless $B \rightarrow PP$ decays

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Abstract. We perform a global fits to charmless $B \rightarrow PP$ decays which independently constrain the $(\bar{\rho}, \bar{\eta})$ vertex of the unitarity triangle. The fitted amplitudes and phase are used to predict the branching ratios and CP asymmetries of all decay modes, including those of the B_s system. Different schemes of SU(3) breaking in decay amplitude sizes are analyzed. The possibility of having a new physics contribution to $K\pi$ decays is also discussed.

Although charmless modes are rare processes, they are very sensitive to the smallest CKM matrix elements through decay amplitudes and mixing. With more modes being observed and measured at higher precisions, it becomes possible to use purely rare decays to provide a independent determination of the unitarity triangle vertex $(\bar{\rho}, \bar{\eta})$, expressed in terms of the Wolfenstein parameters, without reference to the charmonium modes. It is therefore interesting to see whether the charmless B decay data alone also provide a CKM picture consistent with other constraints and to search for indication of new physics. There has been several global fits using flavor isospin, SU(3) invariant matrix elements [1] or flavor flow topological diagram[2]. In this talk, we present an updated global χ^2 fits to the available charmless $B \rightarrow PP$ decays using the flavor diagram approach [3]. The fitting parameters include the Wolfenstein parameters A , $\bar{\rho}$, and $\bar{\eta}$, magnitudes of different flavor amplitudes, and their associated strong phases. To take into account SU(3) breaking, we also include breaking factors of amplitude sizes as our fitting parameters in some fits. In the present approximation, we consider five dominant types of independent amplitudes: a “tree” contribution T ; a “color-suppressed” contribution C ; a “QCD penguin” contribution P ; a “flavor-singlet” contribution S , and an “electroweak (EW) penguin” contribution P_{EW} . The former four types are considered as the leading-order amplitudes, while the last one is higher order in weak interactions. There are also other types of amplitudes, such as the “color-suppressed EW penguin” diagram P_{EW}^C , “exchange” diagram E , “annihilation” diagram A , and “penguin annihilation” diagram PA . Due to dynamical suppressions, these amplitudes are ignored in the analysis. This agrees with the recent observation of the $B^0 \rightarrow K^+K^-$ decay.

To see the effects of SU(3) symmetry breaking, we consider the following four fitting schemes in our analysis: 1) exact flavor SU(3) symmetry for all amplitudes; 2) including the factor f_K/f_π for $|T|$ only; 3) including the factor f_K/f_π for both $|T|$ and $|C|$; and 4) including a universal SU(3) breaking factor ξ for all amplitudes on top of Scheme 3. To reduce the number of parameters, we assume exact flavor SU(3) symmetry for the strong phases in these fits. In addition to the observables in $B \rightarrow PP$ modes, we also include $|V_{ub}| = (4.26 \pm 0.36) \times 10^{-3}$ and $|V_{cb}| = (41.63 \pm 0.65) \times 10^{-3}$ as our fitting observables.

In the first step, we include only $\pi\pi$, πK and KK modes. The four scheme gives $\chi^2/dof = 18.9/12, 18.0/12, 16.4/12$ and $16.1/11$ respectively. The naive factorization motivated scheme 3 has the best goodness-of-fit. The best-fitted values of the parameters in their 1 σ ranges (amplitudes in units of 10^4eV) are

$$\begin{aligned} |T| &= 0.571^{+0.045}_{-0.040}, & |C| &= 0.360 \pm 0.046, & \delta_C &= -49.3 \pm 9.1, \\ |P| &= 0.122 \pm 0.002, & \delta_P &= -17.6 \pm 2.7, & |P_{EW}| &= 0.011 \pm 0.001, \\ \delta_{P_{EW}} &= -18.7 \pm 4.0 . \end{aligned} \quad (1)$$

The results show a nontrivial strong phase δ_C as well as a large $C/T \sim 0.63$. The fitted P_{EW} agrees with the SM expectation. However, the low $S(\pi^0 K_S)$ observed by the experiment is not reproduced, which is the main source of the inconsistency of the fit. In this scheme the following results for the weak phases α , β , and γ are obtained

$$\alpha = (83^{+6}_{-7})^\circ, \beta = (26 \pm 2)^\circ, \gamma = (72^{+4}_{-5})^\circ . \quad (2)$$

The allowed range for $\bar{\rho}, \bar{\eta}$ is given in Fig.1a, which shows an overall agreement with the other global fits[4]. However, our results favor a slightly larger γ and the area of the UT.

We further carry out the analysis with the inclusion of modes with η and η' in the final state. In all the schemes a large S is found, in particular $S = 0.047 \pm 0.003$ for scheme 3, which is driven by large $Br(\eta' K)$. Other hadronic amplitudes remain almost unaffected. Note that the fit results favor an even larger γ , which can be clearly seen from Fig.1b and the following best fitted phase angles

$$\alpha = (80 \pm 6)^\circ, \beta = (23 \pm 2)^\circ, \gamma = (77 \pm 4)^\circ . \quad (3)$$

Using the fitted parameter, we make predictions for all B_s modes. In particular, we predict $Br(K^+ K^-) = (18.9 \pm 1.0) \times 10^{-6}$ which on the lower side but still consistent with the latest CDF data $(24.4 \pm 4.8) \times 10^{-6}$. Due to the large S obtained from the fits, we find large predictions for $Br(\eta' \eta') = (48.3 \pm 4.1) \times 10^{-6}$ and $Br(\eta \eta') = (22.4 \pm 1.5) \times 10^{-6}$.

In expectation of possible new physics contributions to the $K\pi$ decays to account for the observed branching ratio and CP violation pattern [5, 7, 6, 8], we try in Scheme 3 fits with a new amplitude added to these decays. More explicitly, a new amplitude $N = |N| \exp[i(\phi_N + \delta_N)]$ is included in the $B \rightarrow \pi^0 K^-$ and $\pi^0 \bar{K}^0$ decays in such a way that effectively,

$$c' \rightarrow Y_{sb}^u C - (Y_{sb}^u + Y_{sb}^c) P_{EW} + N . \quad (4)$$

where $Y_{q_1 q_2}^q$ stands for $V_{q q_1}^* V_{q q_2}$. This introduces three more parameters ($|N|$, ϕ_N , and δ_N) into the fits. Here we assume that P_{EW} is fixed relative to $T + C$ through the SM relation. The χ_{\min}^2 is found to decrease dramatically from 16.4 to 4.3 in the limited fit with only π , K mesons in the final state. The new physics parameters are found to be

$$|N| = 18^{+3}_{-4} \text{ eV} , \quad \phi_N = (92 \pm 4)^\circ , \quad \text{and} \quad \delta_N = (-14 \pm 5)^\circ . \quad (5)$$

After rescaled with CKM factors, Such a $|N|$ is about three times as large as P_{EW} with a large CP violating phase. With this new amplitudes, the observed low $S(\pi^0 K_S)$ can be accounted for. For more detailed discussions on new physics in P_{EW} , we refer to Refs.[9, 10]. It then is of interest to examine if other modes involving $\eta^{(\prime)}$ mesons follow the similar pattern. Our result shows, however, that in this case the best fitted N is compatible with zero. Possible reasons for that are $S(\eta' K_s)$ is closer to the SM value, and there is no πK CP puzzle in the $K\eta^{(\prime)}$ modes. In both cases, the best fitted CKM parameters $\bar{\rho}$, $\bar{\eta}$ and A remain almost unchanged.

In summary our fits render an area of the $(\bar{\rho}, \bar{\eta})$ vertex slightly deviated from but still consistent with that obtained from other constraints. We predict the branching ratios and CP

